MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2014/2015

EMG4096 – RADAR SYSTEM DESIGN AND ANALYSIS

(TE)

18 SEPTEMBER 2014
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 9 pages with 7 Questions only .

2. There are **TWO** sections in this question paper. Answer all questions (**FIVE**) in **Section A**. Attempt **ONE** out of **TWO** questions in **Section B**. The distribution of the marks for each question is given .

3. Please write all your answers in the Answer Booklet provided .

SECTION A

Question 1

An C-band shipped based radar operates at a frequency of 3000MHz with a pulse width of 0.1us. The radar is used to determine the distance to a ship travelling towards the ship. The targeted maximum detectable range is to be 2000 meters.

(i) Calculate the required pulse repetition frequency (PRF) if range measurement must be unambiguous.

[2 marks]

(ii) Calculate the resolution in range.

[2 marks]

(iii) Calculate the received signal in dBm from a target with radar cross section of $10m^2$ at a distance of maximum detectable range. The transmitted power and the gain of the antenna are 10W and 20dBi respectively.

[3 marks]

(iv) Find the noise floor of this radar system if the effective noise temperature is 650k. (Boltzmann's constant $= 1.38x10^{-23}$J/K)

[3 marks]

(v) Calculate the Signal to Noise Ratio (SNR) of this radar system when the detection range is equal to 2000 meters. Assuming the radar losses is 6dB.

[2 marks]

(v) If the SNR requirement is 10dB, can the described radar system achieve the requirement at the maximum detectable range?

[1 marks]

(vi) Calculate the range that corresponds to SNR = 10dB.

[2 marks]

Continued .....

Question 2

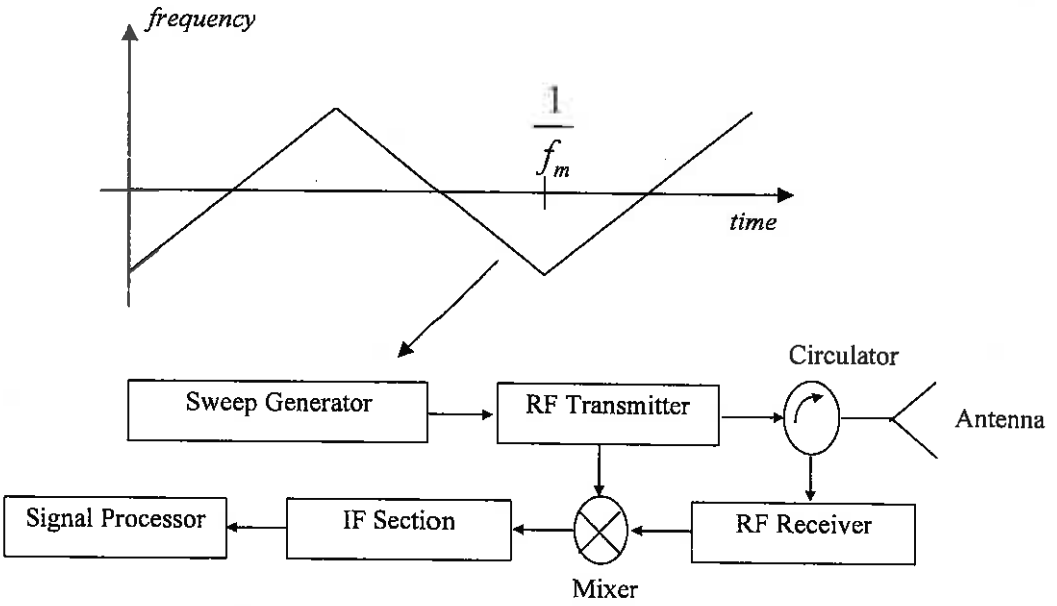

Fig. Q2

Consider Frequency Modulated Continues Wave (FM-CW) radar with a linear FM modulation as shown in Fig. Q2 above. The modulating frequency is 1 kHz, the bandwidth is 500 kHz and the centre frequency is 3.125 GHz. The radar detects a target moving away from the radar, at a range of 10km with a velocity of 80m/s.

(i) Calculate the frequencies present at the output of the mixer.

[6 marks]

(ii) Draw the return echo of the linear FM signal (frequency vs. time). On your drawing, show the relative position of the transmitted signal.

[3 marks]

(iii) If a sawtooth waveform is used instead of a triangular waveform for the modulation signal, determine the frequencies present at the output of the mixer. Given the modulation frequency of the sawtooth waveform is the same as the triangular waveform.

[6 marks]

Continued .....

Question 3

a) An L-band (1.25 GHz) military radar utilizes a staggered waveform with four different pulse repetition frequencies, which are 1500, 1400, 1300 and 1200 Hz.

(i) What is the blind speed if a constant pulse repetition frequency is used which has a pulse repetition period equal to the average of the four periods of the staggered waveform?

[6 marks]

(ii) What is the first true blind speed of the staggered pulse repetition waveform? Note that the integers related by stagger ratio, n_i for these four frequencies are 39, 42, 45 and 49, respectively.

[4 marks]

b) Typical configurations for satellite tracking radars at various radar frequencies are listed as below.

Frequency = 5 GHz
SNR = 10 dB
Range = 850 km
System loss = 6 dB
Pulse width τ_p = 10 us
Noise figure = 5 dB
Antenna Gain = 50 dBi

Compute the minimum peak transmit power (in dBW) required to track the satellite with Radar Cross Section (RCS) = 1 meter^2.

[5 marks]

Continued .....

Question 4

a) A synthetic aperture radar has a range resolution of 5 m in the slant range direction and an azimuth resolution of 7.5 m. Suppose that the pixel spacing is exactly equal to the resolution.

(i) What is the ground range resolution of this instrument if it is operated with an incidence angle of 30°?

[3 marks]

(ii) If the incident angle increase to 60°, what is the ground range resolution?

[2 marks]

(iii) At what incidence angle should the radar use to obtain "square" pixels on the ground?

[5 marks]

(b) Explain what is meant by radar cross section (RCS).

[5 marks]

Continued .....

Question 5

Fig. Q5 shows the block diagram of airborne synthetic aperture radar (SAR) system.

(i) What is the main purpose of using circulator in this design?

[3 marks]

(ii) What is the main disadvantage of the circulator if we wish to transmit high power signal? Propose a possible solution for this disadvantage and draw an appropriate figure to illustrate the design.

[6 marks]

(iii) What is the main objective of Low Noise Amplifier (LNA) in the receiver?

[3 marks]

(iv) What is the main function of the 100MHz oscillator in this design?

[3 marks]

(v) A 500MHz Analog to Digiter Converter (A/D) is used to sample the return echo. What is the minimum allowable sampling rate in this design? Is the proposed A/D is sufficient for this design?

[5 marks]

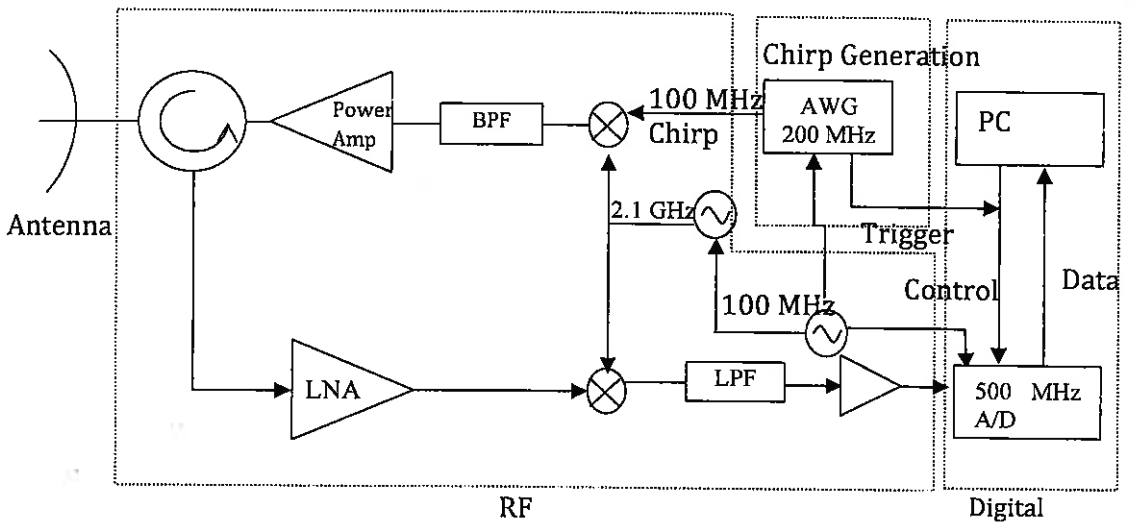

Figure Q5

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SECTION B

Question 6

The AN/SPS-10 surface search radar has the following operating parameters:

peak transmitter power = 200 kW
antenna gain = 33.0 dB
frequency = 5.6 GHz
pulse width = 1.4 us
PRF = 625 Hz
antenna scan rate = 16 rpm
azimuth half-power beamwidth = 1.5 degrees
receiver noise bandwidth = 1 MHz
receiver noise figure = 9.88 dB
system losses ahead of the receiver = 5 dB
false alarm time = 2 days
Plan Position Indicator (PPI) display and operator

(i) Calculate the number of hits (pulse) per scan on a stationary point target.

[2 marks]

(ii) Find P_{fa} and determine the single pulse SNR in dB required to achieve a detection probability of 0.95 (refer to Fig Q6).

[4 marks]

(iii) Determine the integration improvement in dB (noncoherent integration) and the SNR for the total number of pulse as (a).

[6 marks]

[Given the improvement factor report in Peebles as

$$[I(n_p)]_{dB} = 6.79(1+0.235P_D)(1+\frac{\log(1/P_{fa})}{46.6})\log(n_p)$$
$$(1-0.140\log(n_p)+0.018310(\log n_p)^2)$$

where n_p is the number of pulse, P_D is the probability of detection.

and Given the improvement factor as $I(n_p) = \frac{(SNR)_1}{(SNR)_{n_p}}$]

(iv) Calculate the minimum detectable signal power in dBw. (Assume the SNR = 0 dB for this calculation.)

[3 marks]

Continued .....

(v) Calculate the maximum free space detection range in kilometers for a detection probability of 0.9 (with a false alarm time of 2 days) on a 0 dBsm non-fluctuating point target with single pulse.

[2 marks]

(vi) Calculate the maximum free space detection range in kilometers for a detection probability of 0.95 (with a false alarm time of 2 days) on a 0 dBsm non-fluctuating point target with number of pulse equal to (i).

[3 marks]

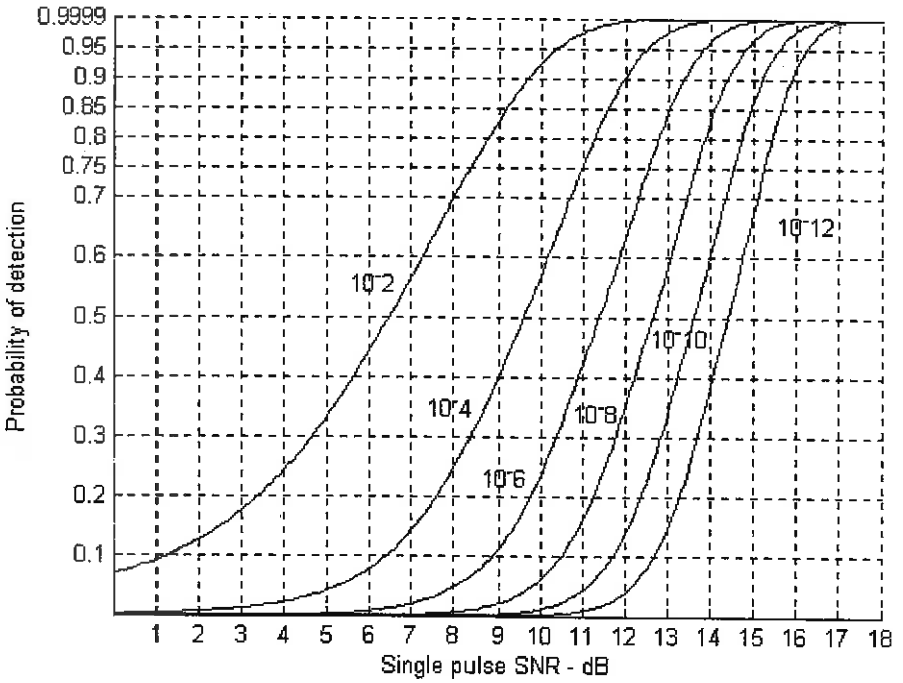

Fig. Q6: Probability of detection versus single pulse SNR for several values of P_{fa}

Continued .....

Question 7

Certain radar has the following specifications: transmit power P_t, gain of antenna G, pulse width $\tau = 5\mu s$, antenna beam width $\theta = 2.5^o$, and wavelength $\lambda = 6cm$. The radar illuminates an area as shown in Fig. Q7. The range from radar to target is 15km and the grazing angle, $\psi_g = 30^0$. The area has a point target with radar cross section (RCS), $\sigma = 20m^2$. The point target is surrounded by grass with a backscatter coefficient $\sigma^o = -30dB$. Calculate:

(i) The area illuminated by a single pulse, A_c.

[5 marks]

(ii) The return power solely from the point target.

[5 marks]

(iii) The return power solely from the background A_c.

[5 marks]

(iv) The signal to clutter (SCR) ratio in dB.

[5 marks]

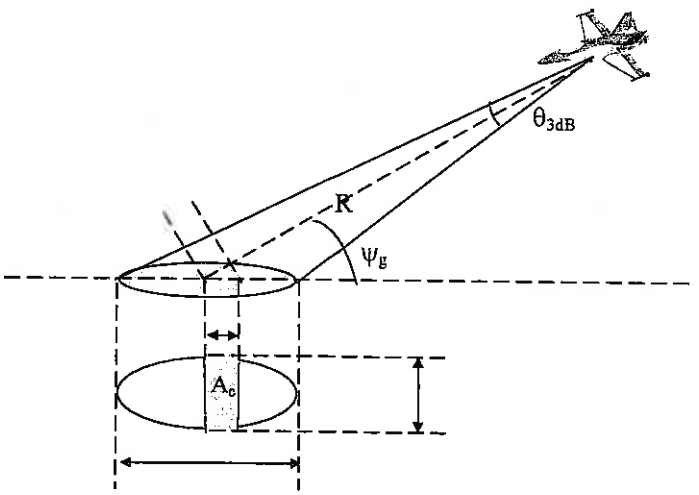

Fig. Q7

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